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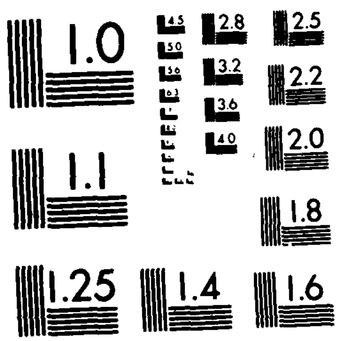

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TECHNICAL REPORT NO. 183-1

HYDRAULIC MODEL INVESTIGATION

AD-A134 656

Spillway Pier Shape at Stoplog Slot for Chief Joseph Dam Columbia River, Washington

SPONSORED BY
U. S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT

CONDUCTED BY
DIVISION HYDRAULIC LABORATORY
U. S. ARMY CORPS OF ENGINEERS
NORTH PACIFIC DIVISION
BONNEVILLE, OREGON

JANUARY 1983

US Army Corps of Engineers
Seattle District

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Chief Joseph Dam project was modified in the late 1970's to accommodate a 10-foot pool raise. Modification included raising and widening of the spillway piers. Inspection of the piers reconstructed early in the modification contract revealed that the as-built pier shape in the vicinity of the stoplog slots was considerably out of tolerance from the design shape. The as-built shape raised concern over potential for cavitation resulting from localized areas of low pressure near the stoplog slots. A 1:30 scale model was used

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to study the pressure regime in the area of the stoplog slot for design shape, three as-built shapes, and three alternative shapes to evaluate limiting criteria for correction of the misalignment if required. Study results indicated that during spillway design flood conditions pressures on the as-built piers tested could result in cavitational damage. During the later stages of construction, the piers conformed closely to the design shape, and the Seattle District decided that modification of the earlier reconstructed piers was not warranted.

PREFACE

Model studies to develop a modification of the Chief Joseph Dam spillway to accommodate a 10-ft pool raise were authorized by the Office, Chief of Engineers, on 20 August 1969 at the request of the U.S. Army Engineer District, Seattle (NPS). Under that authority, model tests were requested by NPS on 16 February 1979 to determine whether construction misalignments on the as-built pier runout occurring during prototype modification would cause cavitation conditions.

The studies were conducted at the North Pacific Division Hydraulic Laboratory from February to December 1979 under the supervision of Mr. P. M. Smith, Director. The tests were conducted by Mr. A. G. Nissila. This report was prepared by Mr. J. L. Lencioni of the Seattle District under the supervision of Mr. R. P. Regan, Chief, Hydraulics Section.

TABLE OF CONTENTS

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
Feet	0.3048	Metres
Miles	1.609344	Kilometres
Feet per second	0.3048	Metres per second
Cubic feet per second	0.283168	Cubic metres per second
Pounds (mass)	0.4535924	Kilograms
Kilowatt-hours	3,600,000	Joules

SPILLWAY PIER SHAPE AT STOPLOG SLOT FOR CHIEF JOSEPH DAM
COLUMBIA RIVER, WASHINGTON

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Chief Joseph Dam is located on the Columbia River in the north central portion of the State of Washington. A location map is shown on figure 1. Principal features of the existing project (plate 1) include a 19-bay spillway and a powerhouse for 27 Francis turbines (total rating 2,069 megawatts (MW)).1/ There are no facilities for passage of fish or navigation past the dam. Overall length of the concrete sections is 4,300 ft; maximum height above foundation rock is 230 ft.

2. Details of the existing spillway are shown on plate 2. The spillway is designed to pass 1,200,000 cubic feet per second (cfs) at a head of 57.3 ft on the crest (reservoir pool elevation 958.8 ft)2/. The ogee section corresponds to the Corps of Engineers' high dam shape for which the design head (41.6 ft) equals 0.73 of the maximum head on the crest. Flow is controlled with 36-ft-wide, 58.2-ft-high tainter gates supported by 13.0-ft-wide piers. Normal full pool is at elevation 956 ft.

3. Project modifications were accomplished between 1976 and 1980 to accommodate a 10-ft increase in normal pool elevation (946.0 to 956.0 ft). The modifications included increasing the spillway pier width from 9.0 to 13.0 ft to support narrower and higher spillway gates.

1/A table of factors for converting U.S. customary units of measurement to metric (SI) units is shown on page iii.

2/All elevations are in ft above National Geodetic Vertical Datum (NGVD).

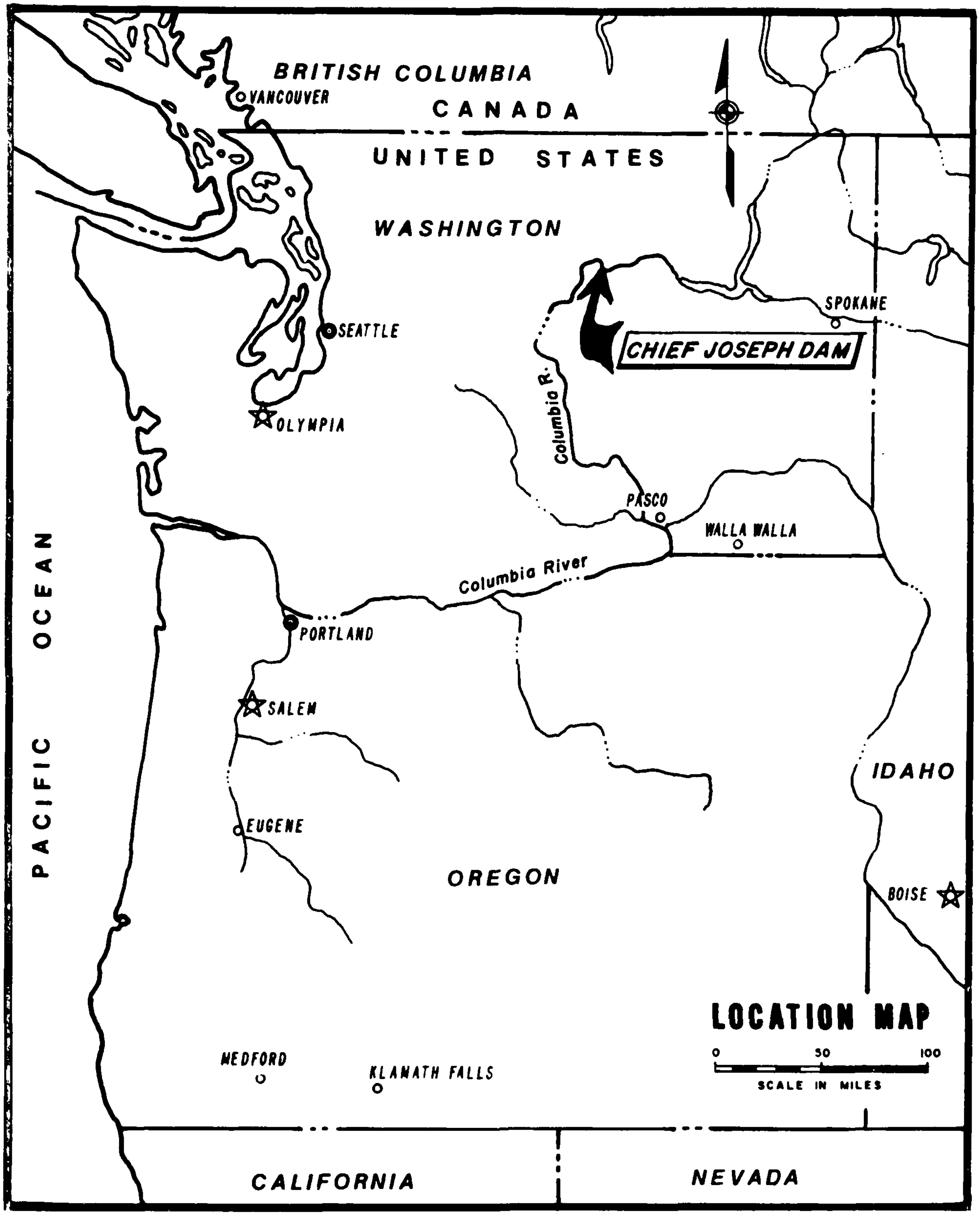

BRITISH COLUMBIA
CANADA
VANCOUVER
UNITED STATES
WASHINGTON
SEATTLE
OLYMPIA
SPOKANE
CHIEF JOSEPH DAM
Columbia R.
PASCO
WALLA WALLA
Columbia River
PORTLAND
PACIFIC OCEAN
SALEM
EUGENE
OREGON
IDAHO
BOISE
LOCATION MAP
0 50 100
SCALE IN MILES
MEDFORD
KLAMATH FALLS
CALIFORNIA
NEVADA

Figure 1

Construction Tolerance Problems

4. Inspection of the initial eight modified piers revealed that the as-built pier geometry in vicinity of the stoplog slot runout was considerably out of tolerance from the design geometry. Theoretical analysis indicated that the combination of as-built geometry and anticipated velocity/pressure regime at the stoplog slot could result in cavitation conditions at or near full gate spillway operation.

Purpose of Model Studies

5. A hydraulic model study was accomplished to determine the cavitation characteristics associated with the misaligned as-built spillway pier geometry. The model study was also designed to provide limiting criteria for correction of the misalignment, if required.

PART II: THE MODEL

6. A 1:30 scale model reproducing two full bays and two half bays of the spillway crest above elevation 792.5 ft, including piers and gates (see photographs 1 through 3 and plate 2), was used to study the pressure regime in the area of the stoplog slot. The center pier was constructed with a removable test section on the right side in order to allow for relatively simple model changes from one test geometry to the n . The left side of the center pier and the other two piers were const ted to the contract shape shown on plates 2, 3, and 4.

7. Seven test sections which reproduced the stoplog slot, 10.5 -- downstream from the slot, and 30 ft above the spillway crest were evaluated. The removable test section depicting the contract design plan is shown in photograph 4. The geometry of the plans tested is shown on plate 3. Plans 1, 2, and 3 represented field surveyed as-built conditions of three of the piers which had the greatest misalignment, while plans 4, 5, and 6 were studied to evaluate limiting criteria for correction of the misalignment, if required.

8. Pressures were measured at the locations shown on plate 4 and described in table 1. These locations were selected because previous model studies[1/] indicated that these locations would be in the lowest pressure area. Average pressures were measured using 1/2-inch-diameter water manometers. High and low instantaneous pressures were measured with electronic pressure cells and oscillographically recorded.

9. Model measurements were converted to prototype values using equations of similitude based on the Froude model law as follows:

Dimension	Ratio	Scale Relation
Length	L_r	1: 30
Discharge	$Q_r = L_r^{5/2}$	1: 4929.50
Pressure	$P_r = L_r$	1: 30

1/Division Hydraulic Laboratory Technical Report 156-1, dated May 1979.

PART III: TESTS AND RESULTS

10. Pressures were measured with two operating conditions: (1) maximum free flow of 1,200,000 cfs (63,157 cfs/bay) depicting spillway design flood conditions and (2) 961,430 cfs (50,600 cfs/bay) depicting a large (40-ft) gate opening with normal full pool elevation 956 ft. The pressure data obtained from the tests are tabulated in tables 2 and 3.

Spillway Design Flood Condition

11. Table 2 shows pressures at spillway design flood condition. With all plans tested, including the contract design plan, average pressures downstream from the stoplog slots were subatmospheric, ranging between -3 and -8 ft of water. The minimum instantaneous pressure measured on any plan tested was -24 ft (plan 5, piezometer 1). The design plan exhibited only slightly better pressure conditions than the other plans. Pressures at piezometers 9-11 on the adjacent side of the test pier and 12-14 on the right side of the left pier, all of which were located at the same locations as piezometers 1-3 of the test pier, recorded essentially the same average pressures observed at the test section. Average pressures on the contract plan were within about 5 ft of those observed during the model studies referenced in paragraph 8. Photograph 5 shows the flow pattern occurring with the spillway design flood condition.

40-Foot Gate Opening Condition

12. Table 3 shows the pressure data observed with a 40-ft gate opening and normal full pool elevation 956 ft. Average pressures with all plans tested were above atmospheric, ranging between +5 and +14 ft of water. Instantaneous pressures were not observed for this condition. Photograph 6 shows the flow patterns for this condition.

PART IV: SUMMARY

13. As-built geometry of the stoplog runout on a number of the Chief Joseph Dam spillway piers modified early in the pool raise contract varied significantly from the contract design geometry. A 1:30-scale model was used to determine whether the as-built condition would cause potential cavitation problems. Seven separate runout shapes representing the contract plan, three shapes based on surveyed as-built data, and three other varying shapes were tested.

14. The model study results indicated that the dynamic pressures on the contract plan pier as well as the as-built pier shapes tested (plans 1-3) are significantly low; however, the pressures on the contract plan are not expected to cause cavitation damage. The as-built condition pressures are slightly lower than the contract plan condition and some cavitational damage can be expected with the spillway design flood condition. Based on the model study results, the Seattle District decided that modification of the as-built piers previously constructed would not be required. As spillway modification progressed, the contractors forming techniques improved and geometry of the piers constructed in the later stages of the contract closely conformed to the contract plan.

TABLE 1

PIEZOMETER LOCATIONS

Piezometer Number	Station	Elevation	Piezometer Number	Station	Elevation
Contract Plan			Plan 3		
1	9+92.8	900.7	1	9+93.0	900.6
2	9+94.4	901.2	2	9+94.9	901.2
3	9+96.2	901.5	3	9+99.0	901.8
4	9+98.0	901.7	4	10+00.9	901.8
5	10+00.0	901.8			
			Plan 4		
6	10+02.5	901.8			
7	10+06.0	901.4	1	9+93.0	900.6
8	10+09.0	900.6	2	9+94.9	901.2
			3	9+97.6	901.7
9	9+92.8	900.7	4	10+00.3	901.8
10	9+94.4	901.2			
11	9+96.2	901.5	Plan 5		
12	9+92.8	900.7	1	9+93.0	900.6
13	9+94.4	901.2	2	9+94.3	901.0
14	9+96.2	901.5	3	9+96.6	901.5
			4	10+00.3	901.8
Plan 1			Plan 6		
1	9+93.0	900.6			
2	9+95.1	901.2	1	9+93.0	900.6
3	9+98.2	901.7	2	9+94.9	901.2
4	10+00.9	901.8	3	9+97.6	901.7
			4	10+00.9	901.8
Plan 2					
1	9+93.0	900.6			
2	9+94.9	901.2			
3	9+97.6	901.7			
4	10+00.9	901.8			

Notes: 1. Details of pier plan shown on Plates 2 and 3.

2. Piezometer locations shown on Plate 4.

TABLE 2

PRESSURES AT STOP LOG SLOTS

Spillway Discharge 1,200,000 CFS, Free Flow, Forebay Elev 958.8

Piezometer Number	Pressure in Feet of Water		
	High	Average	Low
Contract Plan			
1	1	-7	-16
2	3	-5	-15
3	4	-5	-11
4	1	-5	-11
5	2	-5	-12
6		0	
7		1	
8		0	
9		-7	
10		-5	
11		-5	
12		-7	
13		-4	
14		-4	
Plan 1			
1	2	-6	-19
2	-1	-7	-13
3	-1	-6	-13
4	2	-1	-8
Plan 2			
1	10	-8	-21
2	1	-6	-17
3	3	-3	-15
4	1	-3	-12
Plan 3			
1	-2	-8	-19
2	4	-3	-10
3	-1	-6	-9
4	0	-4	-7
Plan 4			
1	-1	-8	-19
2	9	-4	-12
3	5	-1	-9
4	7	-2	-9
Plan 5			
1	2	-6	-24
2	3	-8	-13
3	1	-5	-13
4	2	-3	-9
Plan 6			
1	5	-8	-22
2	5	-6	-16
3	2	-4	-13
4	5	-2	-8

Notes:

1. High and low pressures measured with electronic pressure cells and average pressures measured with 1/2-in.-diameter water manometers.
2. Details of pier plans shown on Plates 2 and 3.
3. Piezometer locations listed in table 1 and shown on Plate 4.

TABLE 3

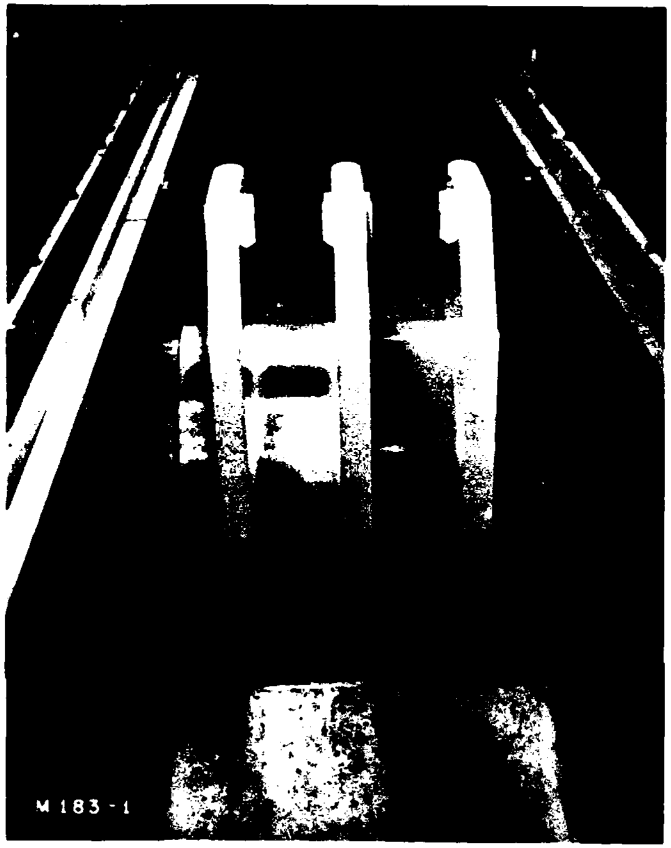
PRESSURES AT STOP LOG SLOTS

Spillway Discharge 961,430 CFS, Gate Open 40 Ft, Forebay Elev 956.0

Piezometer Number	Plan						
	Contract	1	2	3	4	5	6
	Average Pressure in Feet of Water						
1	5	8	5	11	9	6	7
2	8	7	7	9	7	14	8
3	7	8	10	9	10	8	10
4	8	11	9	12	9	9	10
5	7						
6	10						
7	10						
8	7						
9	5						
10	7						
11	7						
12	7						
13	9						
14	8						

Notes: 1. Details of pier plans shown on Plates 2 and 3.

2. Piezometer locations listed in table 1 and shown on Plate 4.



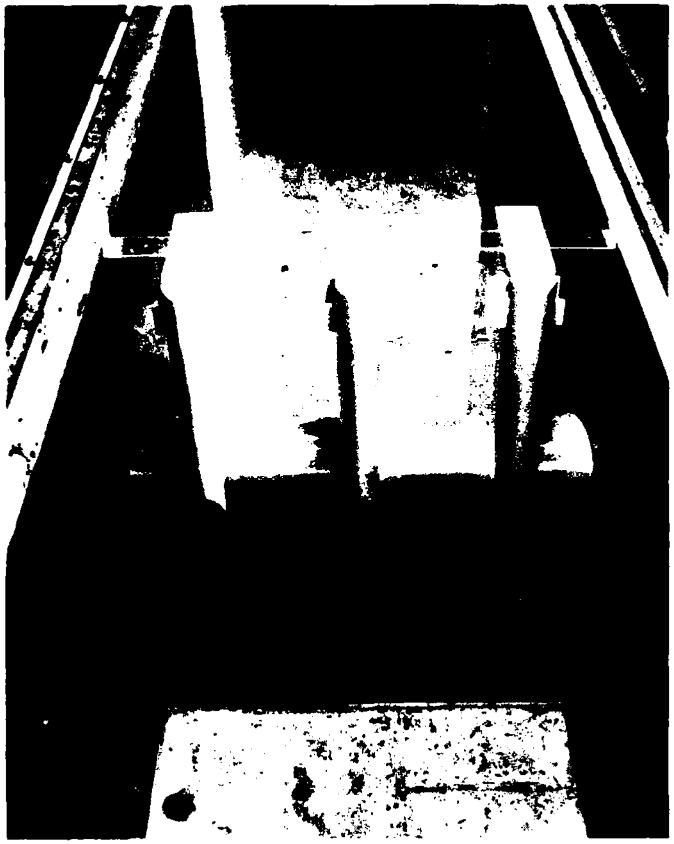
Photograph 1

Looking upstream

Photograph 2

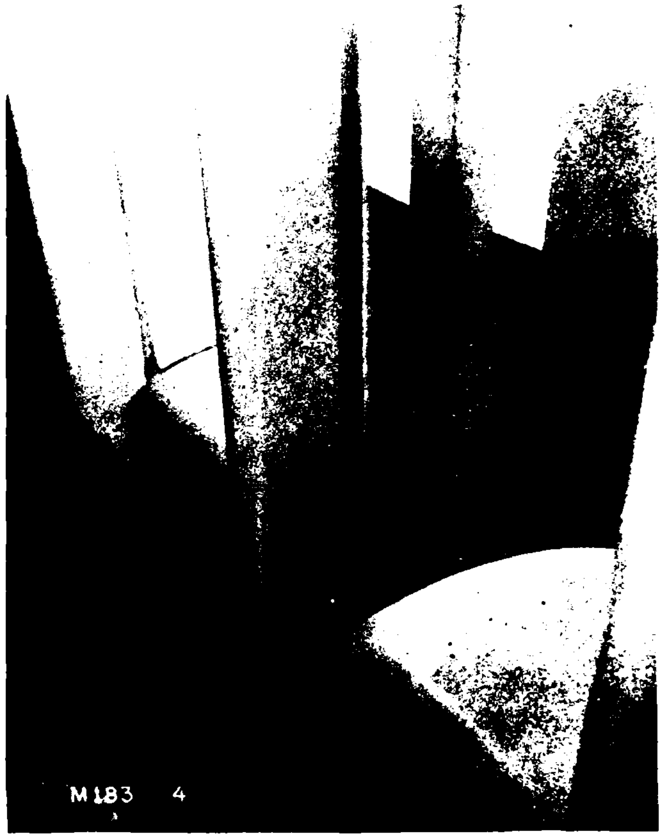
Overhead

Chief Joseph Spillway Pier Model
(with gates removed)



Photograph 3

Looking downstream at model with gates removed



Photograph 4

Close-up of test section with contract plan

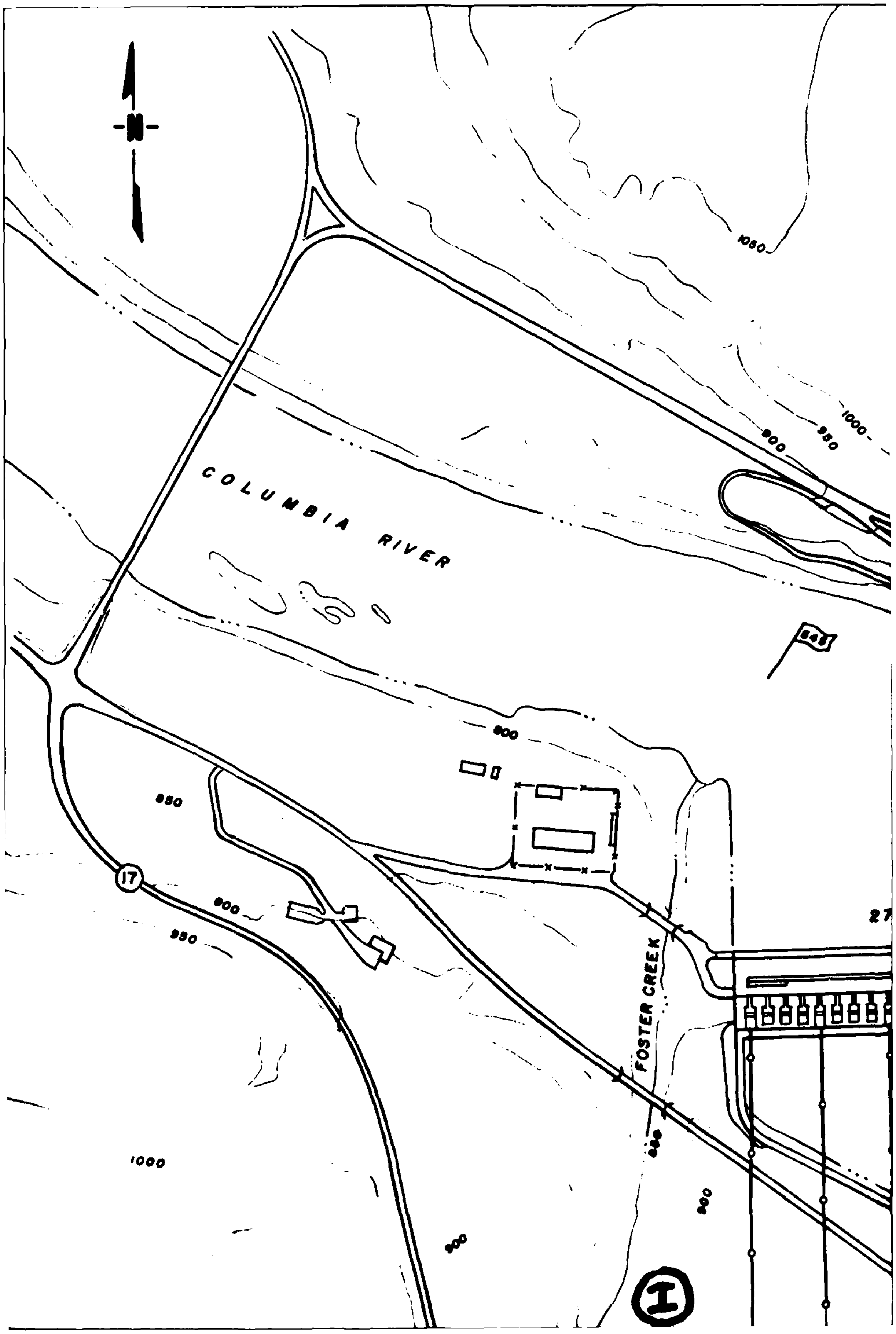
Photograph 5

Spillway discharge 1,200,000 cfs
Free flow, forebay elev 958.8

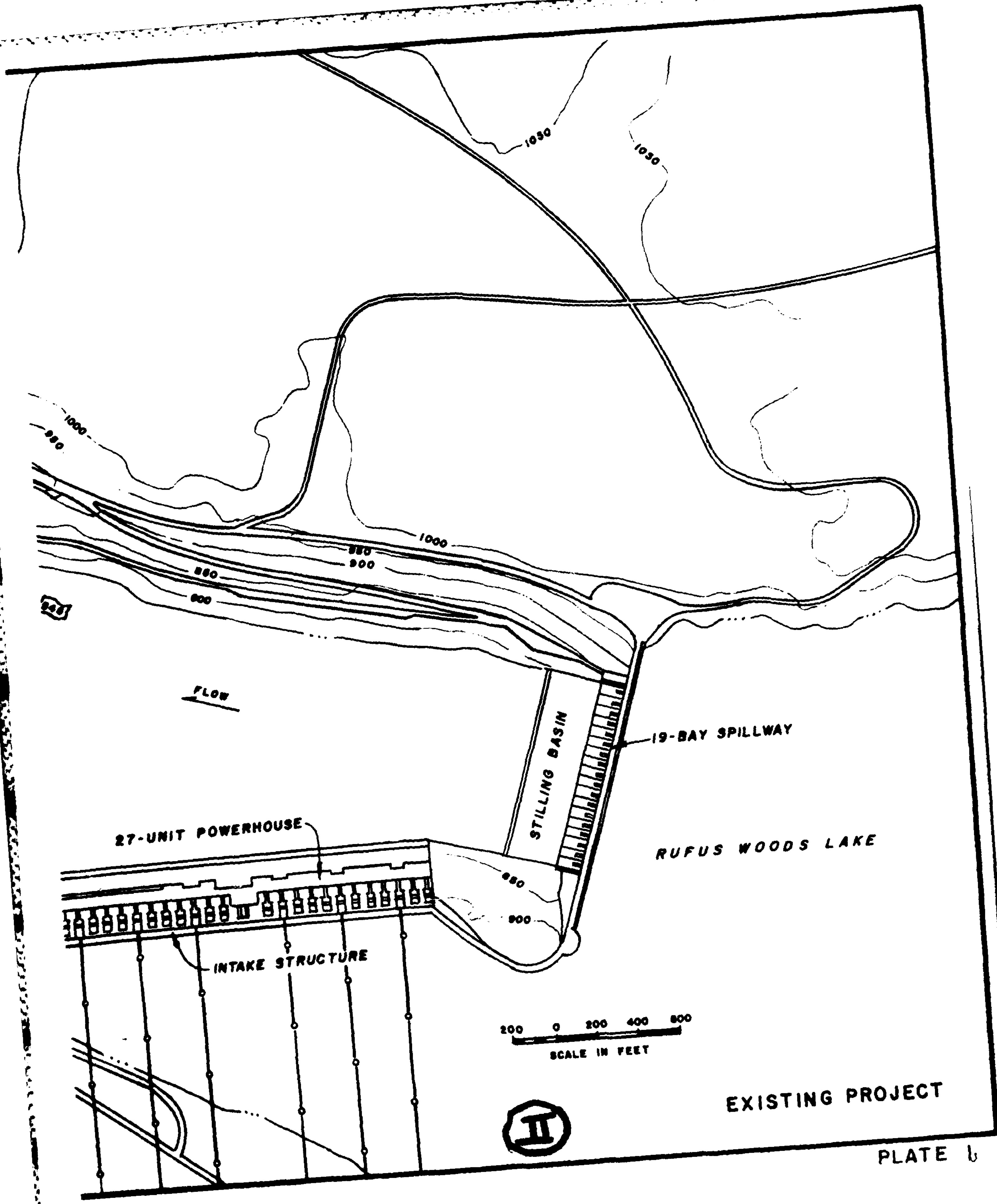
Photograph 6

Spillway discharge 961,430 cfs
Gate open 40 ft, forebay elev 956.0

Typical flow patterns

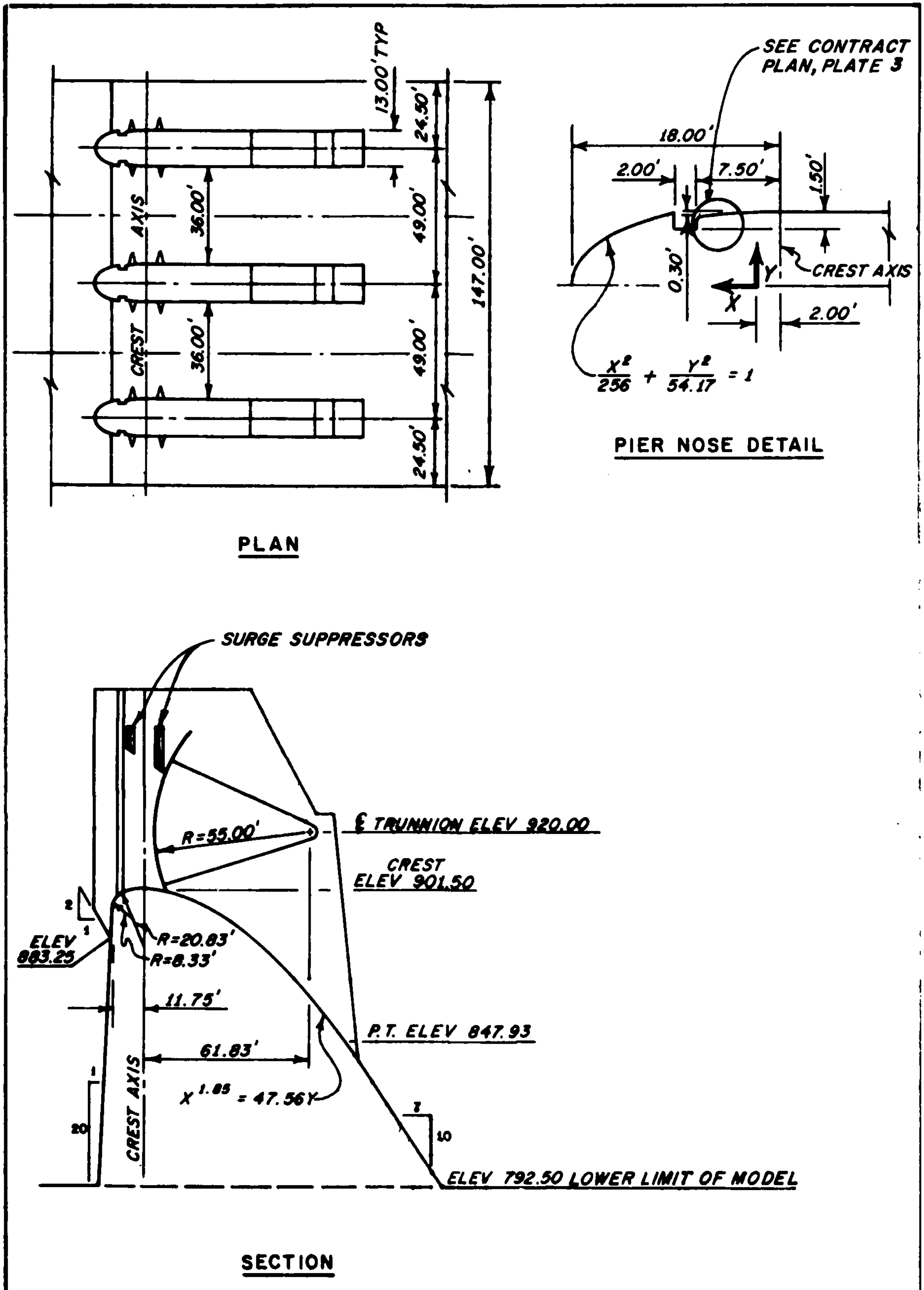


N
COLUMBIA RIVER
1050
1000
950
900
845
850
900
950
17
FOSTER CREEK
1000
900
850
900
27
I

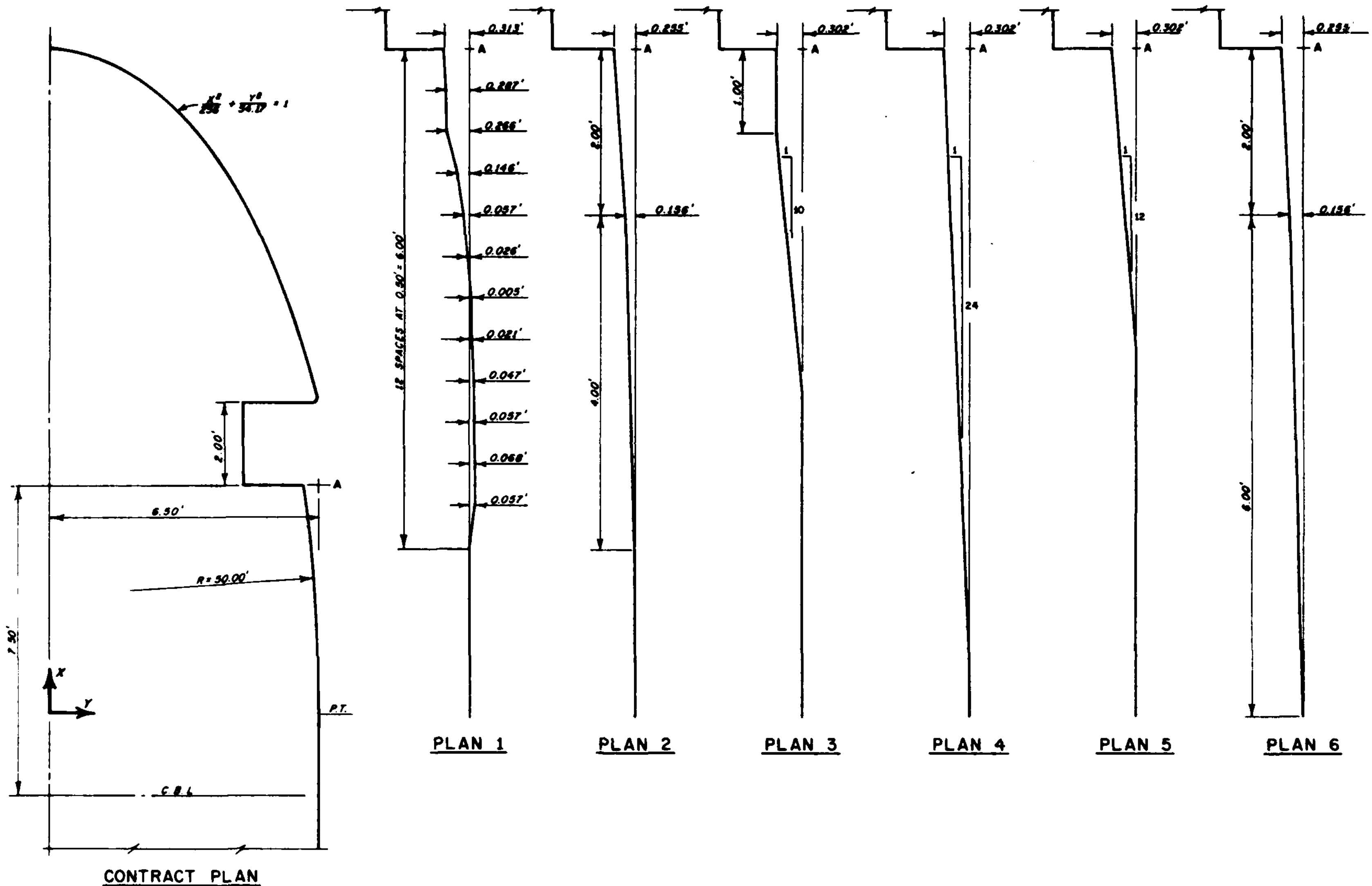


1050
1050
1000
980
1000
980
900
880
900
FLOW
STILLING BASIN
19-BAY SPILLWAY
27-UNIT POWERHOUSE
RUFUS WOODS LAKE
880
900
INTAKE STRUCTURE
200 0 200 400 800
SCALE IN FEET
EXISTING PROJECT

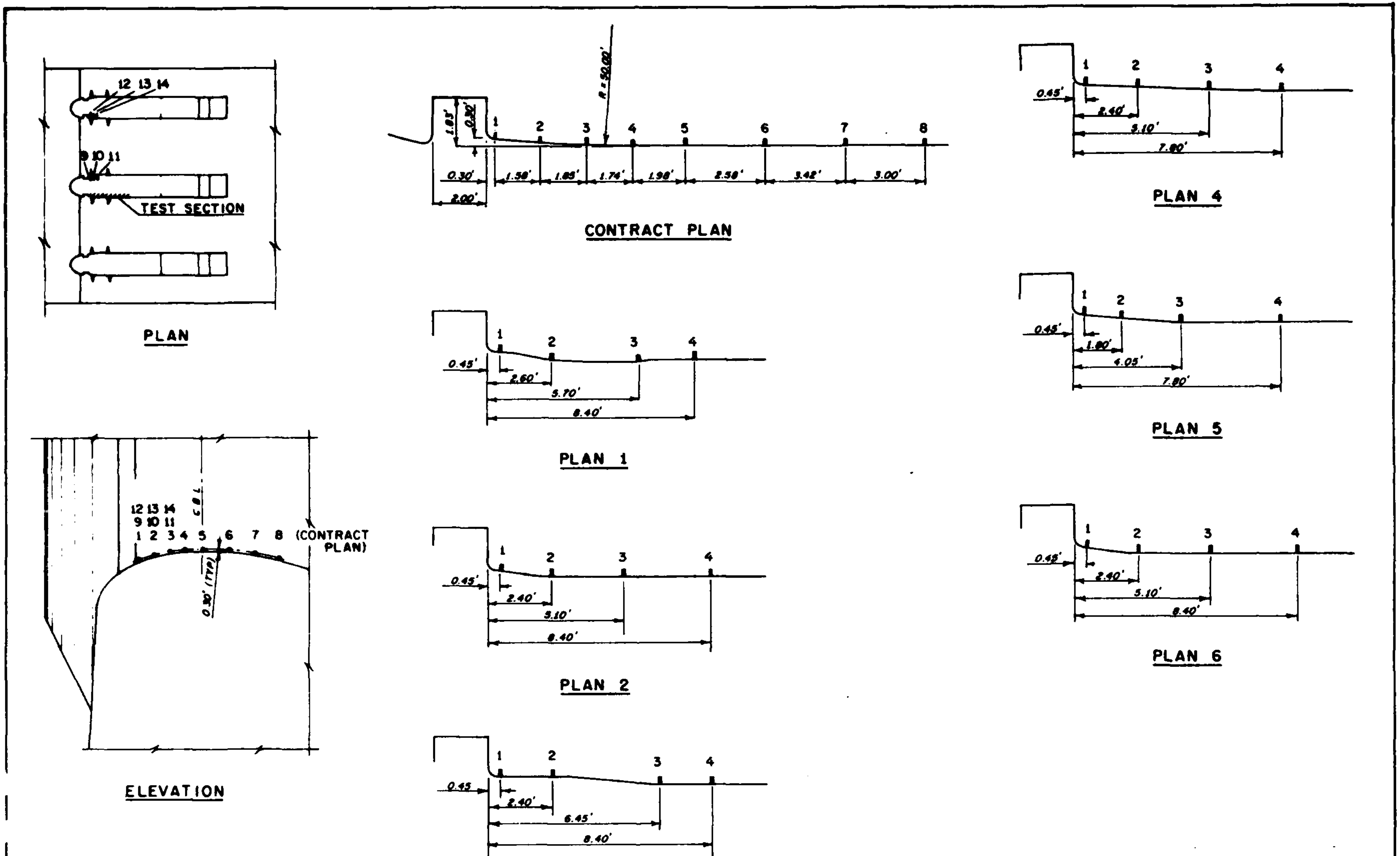
PLATE 6



MODEL LAYOUT



PIER GEOMETRY



PIEZOMETER LOCATIONS

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